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Potential of ASTER and LANDSAT Images for Mapping Features in Western Desert

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Abstract: In Egypt, most of the topographic maps need updating. Also, there are large areas haven't mapped yet. The Western Desert is an example of these poorly mapped areas. Globally, there are many sources of the free satellite images like ASTER and LANDSAT. The study aims to evaluate and improves theses satellite images in order to derive planimetric features for medium scale maps for this important area. Two images of ASTER and LANDSAT were prepared and assessed in order to distinguish their accuracies, the evaluation was based on accurate G.P.S observation data. After registration and geometric correction they were subjected to a process of fusion. The results conclude that: referring to map accuracy standards, the fused image resulted from ASTER and LANDSAT is valid for the intended purpose after registration and geometrically corrected using at least one GCPs for every 15 square kilometers.

Keywords: Planimetric data; Satellite images; Accuracy assessment; Registration; Geometrical corrections; Fusion.

1. Background

Most of the available topographic data in Egypt were collected between 1900 and 1945. These maps are not adequate for the feasibility studies and detailed project planning. Most large areas of Egypt terrain had been mapped by cooperating projects between the Egyptian survey authority and some international agencies. All of these projects used the photogrammetric technique as a map production process. The Egyptian-Finnish project was one of these corporations. The purpose of the project was to produce topographic maps of the Eastern Desert and the Nile Valley. The stereoscopic technique had been used as mapping production process. Photos of scale 1:80,000 were taken, then several G.P.S points had been created as a ground control. The final product was a number of 128 colored topographic maps with scale 1:50,000. The irrigation management system (IMS) project was also another cooperation project with Geonex company as the main contractor at 1989. The goal of the project was to update and produce topographic maps for the areas of the irrigation system to be used for planning, design, operation, management, and maintenance. One of the project products was the mapping of 60,000 km of 1:50,000 and 1:100,000 scales. Topographic maps constructed from scale 1:40,000

photography for Delta and Nil Valley. Similar other projects, the main objective of which is to produce medium scale topographic maps using the photogrammetric technique, all of these projects are outside the western desert area. In general, tracing planimetric features are possible if space geometrically corrected image is available and matched the desired accuracy.

Data from many space-borne remote sensing systems are collected regularly, covering the surface of the earth. However, only a few systems are appropriate for cartographic applications or have even been designed for such purposes. LANDSAT and ASTER images are free sources of these remote sensing data, they are available for all Egypt area and for most of the world. The research aims to study the potential of these satellite images for driving planimetric features of relativity medium scale topographic map for this important and wide part of Egypt (western desert).

2. Introduction

Planimetric mapping from remotely sensed imagery is carried out all over the world, using data from an ever-growing number of sensors. Traditional film cameras are gradually being replaced by digital cameras and scanners, but most mapping still relies on sensors based on airborne platforms [9]. Satellite images represent very important materials source for many reasons. The first one is to produce or revise conventional maps by restitution and interpretation of the image data. The second one is to produce satellite Image maps, thus making use of the integrated information which is available in the pictures. Requirements for the accuracy of geometric correction of satellite imagery vary depending on the application. The planimetric accuracy of some free satellite images like, LANDSAT, ASTER will be discussed to study the ability of these sensors for producing planimetric medium scale maps based on map standard. The study will be a contribution for covering the poorly mapped areas in the western desert of Egypt. The cost effectiveness of mapping from space and the number of ground control points (GCPs) required for images Geo-referencing are correlated factors. Thus we shall pay particular attention for studying the distribution and the amount of ground control points needed to achieve a given level of accuracy over the selected study area.

3. Study area and used data

The selected area was 6 October city, Giza government, Egypt. This city can be considered as part of the western desert, also its topography is semi-flat similar to the most of the western desert. The study area lies in the north west of Egypt between 30°50'N to 30°55'N and 29°55'E to 30°00'E. The area of this city is 670 km², figure 1 shows the location and the extension of the selected study area. Two typs of Satellite images are used, LANDSAT and ASTER. As well as 47 ground control points. The coordinates of these points are measured using GPS system and are used for horizontal accuracy

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assessment The description, properties and the format of the data from LANDSAT and ASTER are discussed in the following sections.

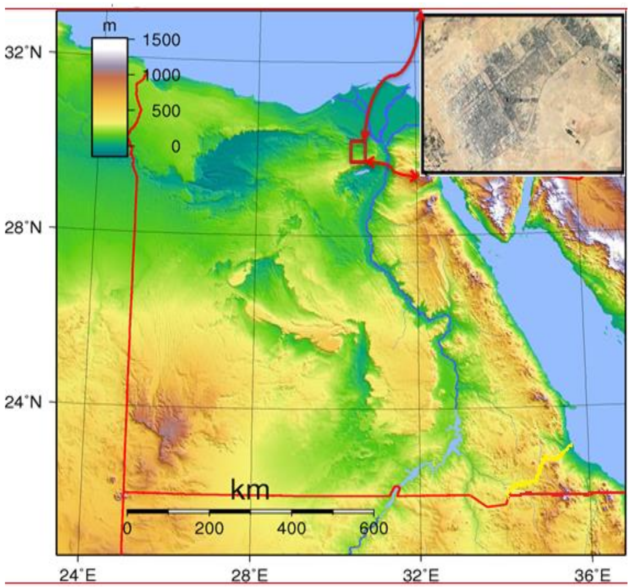

Fig. 1.The location of the selected study area, 6 October city.

3.1. Landsat

On February 11, 2013, LANDSAT 8 was launched, adding to the constellation of Earth imaging satellites. LANDSAT 8 operates in the visible, near-infrared, short wave infrared and thermal infrared spectrums in 11 diffrent bands. Providing moderate-resolution imagery, from 15 meters for panchromatic to 30 meters for multispectral and 100 m for thermal infrared. It captures an average of 700 scenes from altitude 705 km, an increase from the 250 scenes a day on LANDSAT 7. LANDSAT 8 data are freely available for download. The data of LANDSAT 8 can be acquired a number of different ways through the USGS website http://LANDSAT.usgs.gov.The selected study area (6 October) lies at path 176 and row 39

3.2. Aster

ASTER is A joint operation between NASA and Japan's Ministry of Economy, Trade and Industry (METI). Since the year 2000 imagery from ASTER has been available for global observation. ASTER spectral and geometric capabilities include 3 bands in VNIR (visible and near infrared) with 15 m resolution, 6 bands in the SWIR (short-wave infrared) with 30 m resolution, 5 bands in the TIR (thermal infrared) with 90 m resolution and a 15 m resolution NIR along-track stereo-band looking 27.6° backwards from nadir. The stereo band 3B covers the same spectral range of 0.76 µm - 0.86 µm as the nadir band 3N. As LANDSAT, ASTER orbit is at 705 km. ASTER swath width is 60 km. The data of ASTER can be acquired through the USGS earth explorer website http://earthexplorer.usgs.gov.com.

Planned parameters for ASTER and LANDSAT standard products were listed in table 1.

Table 1: Planned parameters for ASTER and LANDSAT

Parameter	LANDSAT	ASTER
Scene width	185 km * 185 km	60 km * 60 km
Product type	Level 1T (terrain corrected)	Level 1T (terrain corrected)
Output format	GeoTIFF	GeoTIFF
Pixel size	15 meters/30 meters/100 meters (panchromatic/mul-tispectral/thermal)	15 meters/30 meters/90 meters (VNIR / SWIR / TIR)
Datum	WGS 84	WGS 84
Orientation	North-up (map)	North-up (map)
Resampling	Cubic convolution	Cubic convolution

3.3. Reference data

For the accuracy assessment, two reference data were used, the first is the ground measurement data. Forty-seven ground control points were collected using Leica VIVA GS15 GNSS GPS. The GCPs were used either as ground control points for model geometrical adjustment or as a checkpoint used for model assessment after geometrical correction. Figure 2 shows the locations of the GCPs over the LANDSAT image of the selected study area.

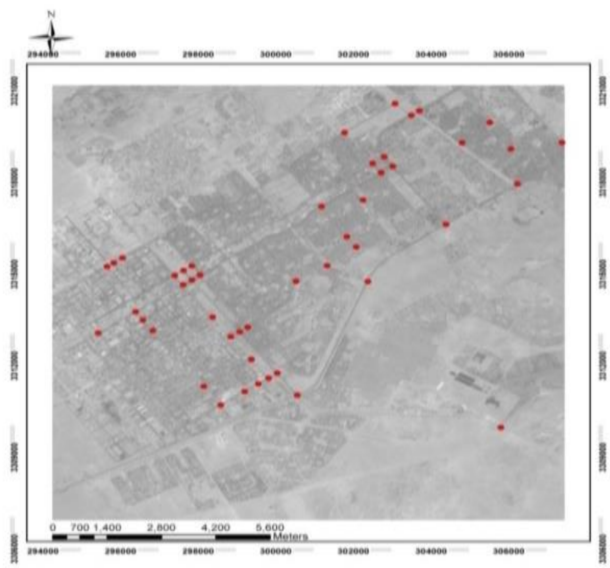

Fig. 2 .The collected GCPs over the LANDSAT image.

4. Methodology

The methodology in this study involves the following steps

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1. Downloading LANDSAT and ASTER images from their website.
2. Verification of the accuracy of ASTER and LANDSAT images in their current state using GPS data.
3. Applying a proposal technique applied for LANDSAT and ASTER images to enhance their accuracies. This technique includes:
   - Registering of low accuracy image to the highest, using some common features and using pixel gray number.
   - Applying geometric correction of the two images of ASTER and LANDSAT.
4. Applying two fusion process:
   - First, fusing ASTER and LANDSAT registered and geometrically corrected panchromatic images.
   - Second, fusing the resulted image from the last step with the multispectral ASTER image of the spatial resolution of 30 m, which is called the ASTER LANDSAT pan sharping.
5. Accuracy assessment and analysis of the final fused image. The flowchart in figure 3 shows the methodology.

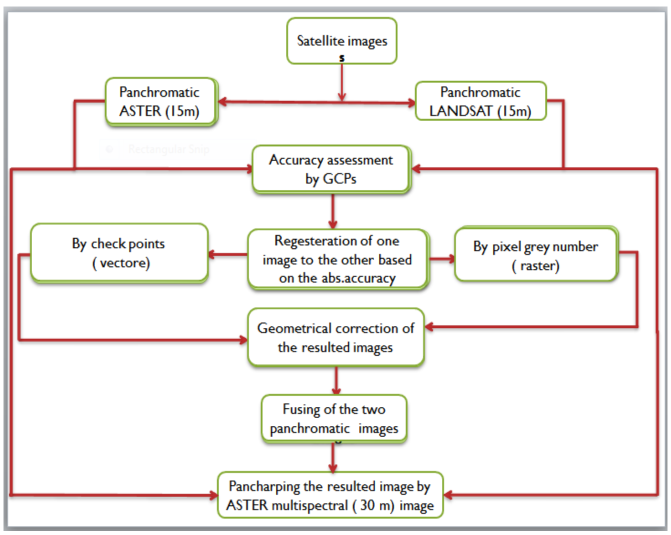


Fig.3. The methodology flowchart.

4.1. Accuracy types and assessment.

Map accuracy standards for NATO class require that 90% of all well-defined points tested to be accurate to within 0.5 mm. A similar level of accuracy has been adopted in the U.S. for the National Map Accuracy Standards and in Canada for class A maps. The accuracy standard as stated is a Circular Map Accuracy Standard (CMAS) [2]. It is somewhat more common to measure Root Mean Squared Error (RMSE). If we assume that the errors have a Gaussian distribution with mean zero, then the relation between CMAS and MSE accuracies, see table 2, can be written as,

CMAS = 1.5174 RMSE

Table 2 : Circular map accuracy standard and root mean square error values for different map scales.

Scale	CMAS (m)	RMSE (m)
1:100,000	50.0	32.92
1:50,000	**25.0**	**16.50**
1:25,000	12.5	8.20
1:10,000	**5.0**	**3.29**

Let dx and dy denote the measured error at the ith check point and n, is the number of checkpoints. The absolute accuracy is:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(dE_i^2 + dN_i^2)}$$

ASTER and LANDSAT were assessed absolutely based on the above equations. The reference data is a number of 47 GCPs collected from ground measurements using GPS system. The RMSE for ASTER and LANDSAT were 20.85 m and 24.83 m respectevely.

4.2. Registration of landsat and aster images

Image registration is the process of matching two images so that corresponding coordinate points in the two images correspond to the same physical region of the scene being imaged. It is a classical problem in several image processing applications where it is necessary to match two or more images of the same scene [10] .

Fusion algorithms depend on the input images being co-registered because they all perform operations on corresponding pixels in both images. They all do something with the two image pixels to create new ones. If the images are not co-registered, the processing will use the wrong pixels, not the corresponding ones and the result will not look natural. This is similar to fusing two panchromatic or multispectral images from two different sensors. If the two images were not true registered, the result will not look natural. Generally, the registration process is usually carried out in three steps. The first step consists of a selection of features of the images. Next, each feature in one image is compared with potential corresponding features in the other image[11]. A pair of features with similar attributes are accepted as matches and are called control points (CPs). Finally the parameters of the best transformation which models the deformation between the images are estimated using the CPs.

In this study, image to image registration is achieved using two different techniques.

- Using the CPs or the common features.
- Using pixel contrast in which, the pixel contrast plays the role of the CPs.

The two techniques will be compared in the following sections.

4.3. Registration by cps (common features)

Image to image registration tools are used by ARC GIS program. The second order polynomial transformation was used to obtain true relative
positions of the panchromatic images of ASTER and LANDSAT. LANDSAT image is registered to the ASTER

image as a base, because, the initial assessment, tables 2, showed its superiority. In that regard, twelve common features (CPs) from each image of LANDSAT and ASTER were selected to be initial input data to the least-squares regression procedure to identify the coefficients of the coordinate transformation [4].

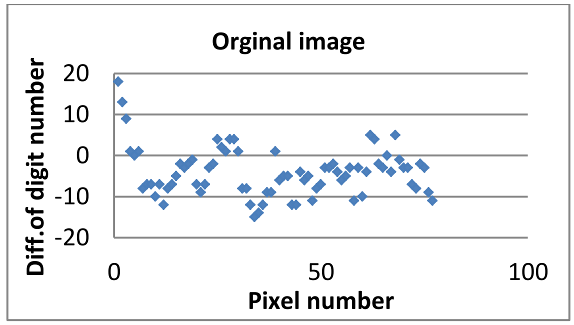
The common strategy is to select many candidates CP (common features) distributed across the ASTER image, determine the equivalent coordinates of these points on LANDSAT, construct the rectification model based on the CP, and then reject those common features that contribute high model residual error. The process of adding candidate CP and rejecting CPs with high model residual error is continued until an acceptable average model error of one pixel is obtained and minimum numbers of CPs are retained [7]. Finally, seven CPs were accepted from the twelve CPs that produced total RMS error (4. 29 m), table 3.

Table 3: Residuals resulted from registration of LANDSAT verse ASTER panchromatic images.

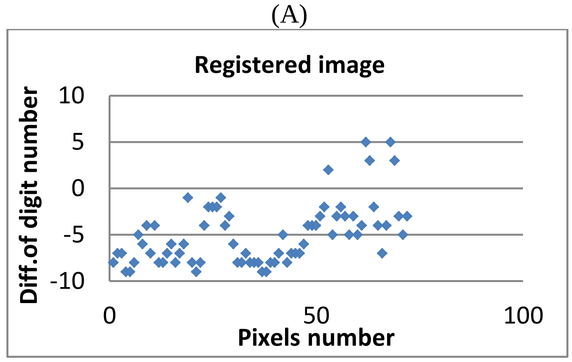
Point .no	Residuals
1	6.77
2	0.73
3	1.85
4	3.78
5	1.89
6	6.72
7	0.74
TOTAL RMSE	4.29 m

4.4. Registration by (image matching)

Registration by image matching or digit number is a suggested new registration technique, in which, the pixels of the two panchromatic images of 15 m resolution of ASTER and LANDSAT were transformed based on their contrast to their digit number or their pixel gray scale using the Matlab software. Then small area formed from nearly 100 pixels were selected from ASTER image and the equivalent pixels were selected from LANDSAT image. Theoretically, the difference matrix of the digit numbers resulted from subtracting the two digit number values of the two images pixels should be closer to a unique value. An inspection using MATLAB was made after fixing ASTER image to find the equivalent of each pixel in the LANDSAT image. In other words, we are searching for the shift that makes the differences between all digit numbers in the two images have constant value and then remove it. After inspection, it was found that coulumns of LANDSAT have to be shifted by 15 m in negative x-direction and no sheft in y-direction. Then the difference matrix of the digit numbers was recalculated again, the differences became closed to unique value. Figure 4 shows the relation between pixel number and the differences between the digit number of LANDSAT and ASTER before and after registration. From this figure, it can be seen that the differences intervals were (-15 to + 18) before shifting, but after correction it is (-10 to + 5), which means that the two images became nearly identical in horizontal positions. The RMSE of LANDSAT image is recalculated again after two cases of the registration (common features and pixel digit number) and is gaiven in table 4.



(A)



(B)

Fig. 4 . Relation between pixel number and the difference in the digit number of LANDSAT and ASTER. (a) before registration, (b) after registration.

Table 4: RMSE of LANDSAT image after regesteration.

item	Registration by common features		Registration by digit number	
RMS (m) Using (47 C. Ps)	E(m)	N(m)	E(m)	N(m)
	17.93	10.88	7.16	9.87
Position error (2D)	20.97		12.19	

4.5. Geometric correction of ASTER and LANDSAT registered images.

In order to correct the LANDSAT and ASTER images geometrically, two distinct sets of coordinates associated with each GCP should be obtained, the image coordinates specified in i rows and j columns, and map coordinates, X and Y measured in a certain coordinate system. Here in this research, the proposed strategy is getting the paired coordinates (i, j, and

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X, Y) from 0,7,9,11, and 13 GCPs respectively from all the collected GCPs. These numbers of the GCPs were used by LANDSAT registered image (by image matching) and ASTER image for deriving geometric transformation coefficients of the model in each case using first and second polynomial ordered to adjust the model. After geometrical correction, the remaining GCPs (47,40,38,36 and 34) were used to assess the model accuracy by Calculating the discrepancies of X, Y coordinates at each checkpoint (CPs). The RMSE in X and Y directions were calculated in each case. Tables 5 and 6 show the models accuracy and the checkpoint accuracy based on the five groups of the GCPs and the remaining C.Ps for ASTER and LANDSAT registered image.

Table 5: The absolute accuracy of LANDSAT registered image after geometric correction.

No. of GCPs	Model accuracy (RMSE/m)		No. of . C.Ps	Checkpoints accuracy (RMSE)		
	1st order	2nd order		E(m)	N(m)	Total Error(m)
0	----	----	47	12.72	14.3	19.1
7	9.2	6.8	40	11.2	13.4	17.5
9	10.1	6.1	38	13.2	10.3	16.7
11	9.1	6.2	36	11.4	11.4	16.1
13	8.9	5.7	34	10.7	11.4	15.6

Table 6: The absolute accuracy of ASTER images after geometrical correction.

No.of GCPs	Model Accuracy (RMSE/m)		No. of . C.Ps	Checkpoint accuracy (RMSE/m)		
	1st order	2nd order		E(m)	N(m)	Total Erroe(m)
0	----	----	47	17.6	11.1	20.8
7	7.4	5.8	34	14.6	10.2	17.8
9	7.3	5.7	36	14.7	9.89	17.7
11	7.5	5.6	38	13.3	10.0	16.7
13	7.9	5.9	40	12.4	9.64	15.7

4.6. Image fusion

LANDSAT and ASTER multispectral images (30 m) contains a higher degree of spectral resolution than their panchromatic images, while their panchromatic images (15m) will have a higher spatial resolution than multispectral images. During mapping, the spatial resolution of the object is vital parameters in the accuracy, while spectral resolutions used for distinction between the objects. A pan sharpened image is a fusion between the multispectral and panchromatic images which gives the best of both image details, high spectral resolution and high spatial resolution [8]. The final product not only has a higher resolution of the panchromatic dataset, but it also has the color associated with the multi-band data set, providing the user with better analysis opportunities. Commonly used technique for combining color (multispectral) raster with gray scale (panchromatic) raster called panchromatic sharpening, more commonly known as pan-sharpening. It is also known as multi-sensor data fusion, image fusion, image integration, and resolution merge [1]. Pan-sharpening combines the spatial properties of higher-resolution panchromatic imagery with spectral information of lower-resolution multispectral imagery to produce a high-resolution multispectral image [3]. Though the main application of pan-sharpening is to combine multispectral imagery with panchromatic imagery, this technique can also be effectively used to integrate image data of two gray scale or panchromatic images. In the present case, two stage of fusion was achieved, fusing the panchromatic ASTER and LANDSAT registered images together, then fusing the resulted image with the multispectral ASTER image which is named as pan-sharpening . There are various pan-sharpening methods available; one of the most commonly used is the simple mean. This algorithm is a simple way of obtaining an output image with all regions in focus. The value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the corresponding pixel of the output image. This is repeated for all pixel values. A Select maximum is another algorithm which based on, the greater the pixel values the more in focus the image. Thus this algorithm chooses the in-focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel [6]. A more advanced algorithm is Applicable, Intensity-Hue-Saturation (IHS) [5]. In this method, Red-Green-Blue (RGB) values are transformed to IHS color space, and then the intensity is replaced by values from the gray scale image. The resultant image is then transferred back to the RGB color model. Esri's ArcGIS software also provides Brovey fusion methods. The Brovey method multiplies each resampled multispectral pixel by the ratio of the corresponding panchromatic pixel intensity to the sum of all the multispectral intensities.

The Esri pan-sharpening transformation uses a weighted average and the additional near-infrared band (optional) to create its pan-sharpened output band (optional) to create its pan-sharpened output bands. The result of the weighted average is used to create an adjustment value that is then used in calculating the output values. All the introduced algorithms have advantages and disadvantages. For example, simple mean is the simplest method of image fusion. But the main disadvantage of this method is that it does not give a guarantee to have clear objects from the set of images. Selecting the maximum resulting in a highly focused image output obtained from the input image as compared to the average method. But, it is affected by blurring effect which directly effects on the contrast of the image. In the advanced algorithms such as Brovey method and Esri, spectral distortion is minimized, it also provides better

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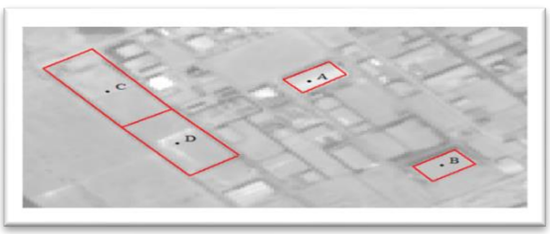
signal to noise ratio than pixel based approach. But in these methods, the final fused image has a less spatial resolution.

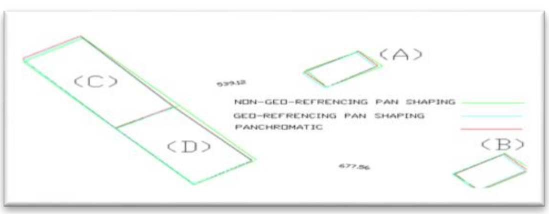
In this study ArcGIS software, with a Brovy algorithm tools package is used to fuse ASTER and LANDSAT registered image together. In our case, two fusing stages were archived:

- First, fusing ASTER and LANDSAT corrected panchromatic images.
- Second, fusing the image resulted from the last step with the multispectral ASTER image of the spatial resolution of 30 m.

The final pan sharping image resulted from ASTER and LANDSAT registered image, was assessed, the RMS in east, north and total are 10.33, 8.13 and 13.14 respectevely. Figure 5 shows a digitization of some buildings and parcel on the original LANDSAT panchromatic image, the registered fused image, and the not- registered fused image. From this figure, one can conclude that considering the original panchromatic image of LANDSAT is the reference, By measurement, the Geo-referenced fused image appeared to have nearly the true dimensions, areas and true geometrical shapes, see table 7. The big areas of the objects in the non-Geo-referencing image is due to the wrong pixel locations in used images, that caused Inflation in the picture and falsity in size.



(Fig.a)



(Fig.b)

Fig. 5. Measurements of the Geo-referencing, the non-Geo-referencing fused image of LANDSAT and ASTER and original panchromatic LANDSAT image. (a) Is their location over LANDSAT image, while (b) is their digitizing forms.

Table 7: Statistical parameters measured from Geo-referencing, non-Geo-referencing fused images, and the original panchromatic LANDSAT image

Item	**Area/ m² (pancharping,Geo**			**Lengths/ m (Perimeters of each figure)**		
	Org.	Georef.	Non-Georef.	Org.	Georef.	Non-Georef.
A	27783	27503	29617	701	694	713
B	29937	29740	32664	708	701	744
C	138711	137576	142945	1613	1599	1615
D	112849	110680	121567	1399	1385	1442
Sum	**309280**	**305499**	**326793**	**4423**	**4381**	**4515**

5. Results and conclusion

The use of satellite remote sensing for the production and revision of planimetric maps is only of interest if the data can be extracted with the appropriate accuracy, completeness, and reliability. It is reasonable for related investigations to study the two major elements of topography, i.e. planimetric and height measurements, separate. In this study, the planimetric accuracy was studied using LANDSAT 8 and ASTER images.

Fusing the satellite image data for LANDSAT and ASTER is a powerful technique in the western desert. In this research the LANDSAT images are registered to the ASTER image. The resulted fused image showed improved accuracy and completeness while maintaining the data characteristics of the input images.

From the obtained results and based on the reference data, without geometrical corrections, ASTER and LANDSAT panchromatic images are not fit to produce planimetric maps of scale 1:50,000, as their RMSEs are greater than NATO accuracy standard. They can be used for producing 1:100,000 planimetric maps or smaller. ASTER and LANDSAT panchromatic images are valid for producing 1:50,000 planimetric features only after registering and geometrically correcting their horizontal positions using at least one GCP per 15 square kilometers (13 GCP over the selected study area), figure 6 shows RMSE for LANDSAT, ASTER and their fused images compared with topographic maps of different scales.

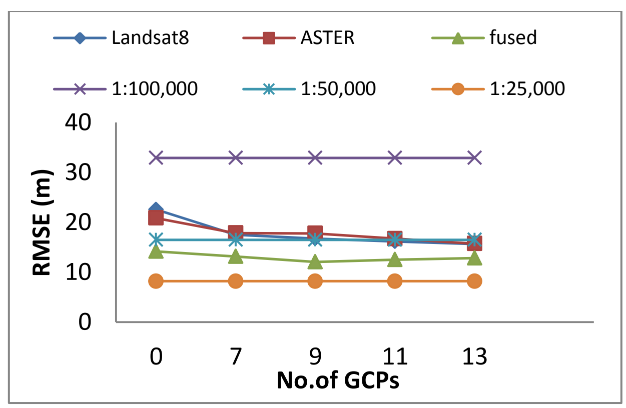


Figure 6: RMSE for LANDSAT, ASTER and their fused images compared with topographic maps of different scales.

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